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**DOMESTIC PREPAREDNESS PROGRAM:
SARIN (GB) AND MUSTARD (HD) CHALLENGE AND
PROTECTION FACTOR (PF) TESTING
OF THE ESSEX PLUS 10 ESCAPE HOOD**

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14. ABSTRACT An escape hood was tested to assess its capability to protect in a chemical warfare (CW) agent environment. Sarin and mustard vapor tests were performed, and there were breakthroughs during the 65-min tests. The hood was also tested to assess its ability to protect the wearer from an aerosolized threat. Human test subjects donned the hoods and entered a corn oil aerosol chamber. Tests were halted due to subjects experiencing claustrophobia.					
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EXECUTIVE SUMMARY

As part of the Domestic Preparedness Program, the Essex Plus 10 escape hood was tested to assess its capability to protect in a chemical warfare (CW) agent environment. Sarin and mustard vapor tests were performed on this hood inspite of the fact that the hood did not meet the leak test requirement. All tests with both agents met breakthrough requirements in <15 min.

The hood was also tested to assess its ability to protect the wearer from an aerosolized threat. Human test subjects donned the hood and entered a corn oil aerosol chamber. The subjects then performed a series of exercises to stress the seals of the hoods. The subjects could not complete the test due to the claustrophobic nature of the hood, and the bellowing created by breathing. No data were recorded because all testing was halted.

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PREFACE

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Edgewood Chemical Biological Center (ECBC) Homeland Defense Business Unit. This work was started in July 2003 and completed in October 2003.

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**DOMESTIC PREPAREDNESS PROGRAM:
SARIN (GB) AND MUSTARD (HD) CHALLENGE AND
PROTECTION FACTOR (PF) TESTING
OF THE ESSEX PLUS 10 ESCAPE HOOD**

1. INTRODUCTION

In 1996, Congress passed Public Law 104-201 (Defense Against Weapons of Mass Destruction Act of 1996), directing the Department of Defense (DoD) to assist other federal, state, and local agencies in enhancing preparedness for terrorist attacks using weapons of mass destruction, including nuclear, biological, and chemical (NBC) weapons. The DoD responded by establishing the Domestic Preparedness Program that same year. This program tasked the U.S. Army Edgewood Chemical Biological Center (ECBC) to perform chemical agent resistance testing of various types of protective respirators that might be used by emergency and HAZMAT personnel responders to a terrorist event.

Personnel who are present at the scene of a terrorist incident that involves NBC, and who are not part of responder personnel, can be expected to leave the scene if circumstances permit. In such situations, an escape safety filter hood should be donned to enable personnel to breathe clean air before they arrive at a safe location remote from the original incident site. A number of safety devices are commercially available that protect against smoke, toxic fumes, aerosols, carbon monoxide, and other gases and vapors that would be harmful if breathed in. Almost none of these devices have been tested against chemical agents to assess the degree of resistance to the agents. Consequently, a widely used escape hood was tested to determine its resistance to chemical agents. The escape hood tested was the Plus 10 Breathing Unit, manufactured by Essex PB&R. The units were purchased on the open market.

2. OBJECTIVES

The objectives of this testing were to subject the escape hood to a high vapor challenge of GB (sarin, a nerve agent) and HD (mustard, a vesicant), and monitor the inside of the hood for presence of agent. Another objective was to determine a protection factor (PF), determined with human subjects and using the standard U.S. Army procedure. At the time of testing, no U.S. Government regulatory agency has yet issued specifications for agent resistance of escape hoods, but NIOSH and DoD are actively pursuing such specifications. For the agent testing, the hood was mounted on a suitable test fixture operated by a breather pump. For this project, a minimum time of 15 min (30 min desirable), resistance to penetration by agents was used; these times have been used previously for the escape mask. The total test time was set at 65 min.

3. CHEMICAL AGENT TESTING

Three escape hoods were tested against each agent, GB and HD. For each test, the escape hood was mounted on a test fixture called SMARTMAN (SiMulant Agent Resistant Test MANikin) that is installed in an exposure (test) chamber. The SMARTMAN is connected to a breather pump to simulate a person breathing inside the hood. Agent vapor was generated to a specified concentration in air, and the mixture was passed through the exposure chamber. The inside of the hood was monitored for presence of agent.

3.1 Chemical Test Equipment.

3.1.1 Vapor Generator.

GB and HD vapors were generated by using a syringe pump to inject liquid agent into a heated tee in the air dilution line. The rate of injection was such that the concentration of vapor was controlled to that specified in the test plan. The agent vaporized in the heated tee, was carried by the dilution air into the mixing chamber, thence into the exposure chamber. An Ambient Air Analyzer (MIRAN), Model 1A, was used to monitor the concentration in the test chamber during the test.

3.1.2 Exposure Chamber.

The test chamber is a Plexiglas box approximately 2 ft³, with a removable front panel and four legs on the bottom about 4 in. long, which allow air to flow under the chamber when it is located inside a fume hood. A test fixture, called SMARTMAN, which is a human head form and half-torso, with a movable face piece and an inflatable peripheral seal, is attached to the floor of the chamber. The mouth orifice of the face piece is connected by a large tube to a breather pump; there are also two sampling tubes in the nose, one in the eye, and one in the forehead. All these tubes pass down through the interior of the head form, down through the floor of the chamber, and connect to remote detectors and the breather pump, or other monitoring devices, such as pressure gauges. Since agent-air mixture passes through the chamber during the test, the outlet ports on top of the chamber are covered by military M12A1 filters to scrub agent from the air passing through. Other ports in the chamber walls are used for introducing the agent challenge into the chamber, to attach pressure gauges for monitoring pressure, to introduce oil aerosol for preliminary leak testing of an installed respirator, or to monitor the agent concentration inside the chamber.

3.1.3 Breather Pump.

The military Breather Pump E1R1 (Jaeco Fluid Systems, Exton, PA) was used to simulate breathing through the hoods. This is a reciprocating pump that produces a sinusoidal breathing pattern by means of a gearing system that incorporates a Scotch Yoke. The pump produces smooth peak flows approximately pi times the minute volume. The minute volume (liters pumped in 1 min) and the number of strokes (breaths) per minute can be adjusted.

3.1.4 Leak Detector, TDA-99M.

This leak detector is based on generating a polydispersed ($<1\ \mu\text{m}$ diameter) aerosol of Emery 3004 oil. The aerosol is directed to the outside of the test hood and a sample of air is taken from inside the hood back to the detector, where a light scattering chamber detects aerosol particles and compares the concentration to that of the original concentration. The readout is expressed as percentage.

3.1.5 MINICAMS, Miniature Continuous Air Monitoring System.

The MINICAMS is a gas chromatograph equipped with a flame photometric detector and a preconcentrator tube. The preconcentrator tube is a small tube containing an adsorbent material to scrub out agent vapors contained in a sample of air drawn through it for a set period of time. The tube is then heated to desorb the agent and introduce it into the column and subsequently the detector. By preconcentrating the agent, the detection limit is lowered. The MINICAMS software calculates the amount of agent detected over the sampling period.

3.2 Chemical Agent Test Methods.

Since it would be prohibitively expensive to test a statistically significant number of escape hoods, only three hoods were tested against each agent.

3.2.1 GB Vapor Procedure.

The escape hood was mounted on a test fixture (Figure), SMARTMAN, inside a clean exposure chamber, equipped with a breather pump. The pump was turned on, and the hood was checked for leakage, using aerosols generated by the TDA-99M Leak Tester. The leak test will give an indication of leak paths to the inside of the hood; usually the hood is not tested with agents if the leak test results are $>0.0001\%$. The hood was then installed on a SMARTMAN in an agent (GB) exposure chamber, and was leak tested again. Then GB vapor was generated as described above and passed into the test chamber, while the breather pump operated the escape hood. The inside of the hood was monitored by MINICAMS at the eye and nose sampling ports of the SMARTMAN. The test was terminated after 65 min or at the time the concentration of agent inside the hood became greater than the breakthrough criterion. The conditions for the GB test are shown in Table 1.

Table 1. GB Test Conditions

Challenge Concentration, mg/m^3	1000
Breakthrough concentration, mg/m^3	0.008
Breathing rate, L/min	40 ± 1
Breathing rate, breaths/minute	35 ± 2
Total test time, minutes	65
Temperature, C	25 ± 3
Relative Humidity, %	50 ± 5



Figure. Plus 10 Escape Mask on SMARTMAN

3.2.2 HD Vapor Procedure.

The escape hood was mounted on a test fixture, SMARTMAN, inside a clean exposure chamber, equipped with a breather pump. The pump was turned on and the hood was checked for leakage, using aerosols generated by the TDA-99M Leak Tester. The leak test will give an indication of leak paths to the inside of the hood; usually the hood will not be tested with agents if the leak test results are $>0.0001\%$. After the leak test, the hood is mounted on a SMARTMAN in an agent (HD) test chamber and the leak test is repeated. Then HD vapor is generated as described above and passed into the test chamber, while the breather pump operates the hood. The inside of the hood was monitored by MINICAMS at the eye and nose sampling ports of the SMARTMAN. The test was terminated after 65 min or at the time the concentration of agent inside the hood became greater than the breakthrough criterion. The conditions for the HD test are listed in Table 2.

Table 2. HD Test Conditions

Challenge Concentration, mg/m^3	200 ± 10
Breakthrough concentration, mg/m^3	0.003
Breathing rate, L/min	40 ± 1
Breathing rate, breaths/minute	35 ± 2
Total test time, minutes	65
Temperature, C	25 ± 3
Relative Humidity, %	50 ± 5

4. PROTECTION FACTOR (AEROSOL) TESTING

A second test was attempted to determine the hood's ability to protect the wearer from an aerosol threat. This test involved human test subjects donning the hood and entering a chamber filled with a challenge concentration of corn oil aerosol. This aerosol is kept between 20 and 40 mg/m³, and the particle size is between 0.4 and 0.6 micron Mass Median Aerodynamic Diameter (MMAD). That concentration and size ranges are what best simulate chemical and biological agent aerosols. While in the chamber the subjects perform exercises designed to stress the seals of the equipment. If the hood were to leak, the corn oil aerosol would enter the hood and be sampled by the laser photometers. The measure of the hood's performance for this test is the PF.

PF Testing Procedures.

Prior to testing 12 hoods were received for testing. All 12 had a standard U.S. Army probe placed just above the filtering unit approximately where the subject's eyes and nose would be.

On test day, 30 subjects arrived at the PF Test Facility to participate in the test. Twenty-four subjects were chosen out of the 30. The subjects were then acclimated to the facility and introduced to the testing procedures by way of a volunteer agreement. The subjects were instructed that if they could not wear the hood for the entire length of the test, they could remove the hood and exit the chamber. The first 12 subjects were then prepared to start the test. They donned the hood with the help of PF Test Facility personnel. A silicone sampling tube was attached to the probe in the hood and the subjects entered the chamber. Once inside, they attached their sampling tubes to other tubes that are connected to laser photometers outside of the chamber. Before a complete 8-min trial could be completed, a majority of the subjects had removed their hoods and exited the chamber. They claim that the hood was very claustrophobic and they could not wear it for the entire test. No PF data was recorded, and all testing was halted.

5. RESULTS

5.1 Agent Tests.

The aerosol leak test results on all the escape hoods ranged from 0.003 to 0.009%. Usually no agent tests are run if the leak tests are >0.0001%. However, to generate data to completely characterize the escape hood, GB and HD tests were performed in spite of the indicated leaks.

The monitoring data from the MINICAMS are charted as breakthrough concentration versus time, and as cumulative Ct (mg-min/m³) versus time. Each test has two charts, and they are shown in the Appendix. As expected from the leak test results, the agent tests reached breakthrough requirements in <15 min, the minimum requirement for an escape mask.

5.2

PF Tests.

No data was recorded for the PF test because of the inability of the subjects to wear the hood for an entire trial. The subjects could not wear the mask because of the claustrophobic environment it created due to the bellowing of the hood during breathing.

APPENDIX

CHEMICAL AGENT TESTING

BREAKTHROUGH DATA











